TECHNICAL CHANGE AND HUMAN CAPITAL ACQUISITION IN JAPANESE AND U.S. LABOR MARKETS

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The first full paragraph should read

Innovative firms are also more likely to use highly educated and technically skilled workers, especially at the outset of a new technology when experience is limited.

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TECHNICAL CHANGE AND HUMAN CAPITAL ACQUISITION IN JAPANESE AND U.S. LABOR MARKETS[1]

The contribution of education to productivity growth is widely accepted among economists and is reflected in its inclusion in growth accounting studies. Less well understood is the role played by post-schooling investments in human capital, such as training or informal learning on the job. What kinds of training are most important for productivity growth? Do these tend to be general skills or firm-specific skills? How do labor markets provide price signals to induce investments in the appropriate kinds of training? What kinds of employment relationships and compensation schemes are needed to encourage investments in skills required by technical change? Answers to these questions should provide insights into how labor markets function to facilitate technical change and productivity growth.

A comparison of how U.S. and Japanese labor markets operate and the way in which they facilitate productivity growth is particularly interesting. Some observers have sought to explain higher rates of productivity growth in Japan than in the United States in terms of differences in labor market organization, contrasting Japan's unique institutions of lifetime employment (*syushin koyosei*) and seniority-based wage compensation (*nenko joretsu seido*) with a spot-market characterization of the way U.S. labor markets operate. These institutions, they argue, instill loyalty and motivate increased work effort and training among Japanese workers, and reduce their opposition to introduction of new technologies. In contrast, weak worker-firm attachment and high labor turnover in the United States may retard work incentives and investments in training, and inhibit innovation.

Neither characterization of U.S. and Japanese labor markets appears well-founded. The culturally based argument for Japan is at odds with

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[1]Forthcoming in NBER-Income and Wealth Conference Volume, *A Comparison of Productivity Growth in Japan and the United States*, edited by Charles R. Hulten, 1989.

evidence that these labor practices are concentrated only among larger firms, that they are of recent origin (after the 1920s), and that they arose with the onset of modern economic growth. Recent studies indicate that long-term jobs are also prevalent in the U.S. labor market (Hall, 1980). However, jobs are typically of shorter duration and have slower rates of wage growth with seniority as compared to Japan (Hashimoto and Raisian 1985). Explanations for these cross-national similarities and differences in employment and wage practices offer potentially important insights into how labor markets operate to facilitate technological change.

This paper presents a model of technology-specific skills that seek to explain why these labor market practices are found in some firms but not in others, and how such practices may be related to productivity growth in the two countries. The model hypothesizes that technological change is associated with a greater demand for firm-specific investments in learning about new technologies and, to the extent that better educated workers are more adept at learning, with a greater demand for a more educated workforce as well. If the potential for technical change differs across industries, differences in specific training and the resulting returns to such investments should be reflected in interindustry wage-tenure profiles (and schooling returns) which vary systematically with the rate of total factor productivity growth. Given the technology gap between the two countries (see Jorgenson, Kuroda and Nishimizu, 1985), the potential for learning is also greater in Japan and, if translated into increased training investments, should be reflected in cross-national differences in wage profiles as well. Another implication of the model--that long-term jobs are more common in technologically progressive industries--follows from skill-specificity, since neither workers nor employers have any incentive to invest in specific training in the absence of a durable employment relationship. This prediction, though not explicitly addressed in this paper, may explain why jobs in Japan tend to be of relatively longer duration.

The paper also addresses the complementary hypothesis that rapid growth itself may induce increased firm-specific training. For a given commodity or product class, the derived demand for skills specific to that particular production technology is larger the more rapid the output growth of that industry. To the extent that demand growth outstrips the supply of these skills in the open market, employers must devote increased resources to developing these technology-specific skills inhouse. Cross-national differences in the rate of output growth--over 8 percent in Japan and about 3.5 percent in the United States over the 1960 to 1979 period--may account for both greater training investments and internalization of skill acquisition in Japanese companies than in American firms. The technology-specific skills and output growth hypotheses are jointed tested in the paper.

Tests of these hypotheses use the May 1979 Current Population Survey for the United States, and the 1977 Employment Status Survey for Japan. Both surveys are broad-based, nationally representative samples of the labor force in the two countries, containing similar information on schooling attainment, work experience, years of tenure on the current job, and earnings. To these data are merged industry indices of total factor productivity growth estimated by Jorgenson, Gollop and Fraumeni (1986) for the United States and Kuroda (1985) for Japan. Because information on firm size is available, the analysis also explores variations in the postulated relationships across firm sizes. Previous studies, both in the United States and in Japan, have found systematic variations in earnings and job tenure across firm size (e.g. Shimada, 1981; Mellow, 1982; Hashimoto and Raisian, 1985). Though these differences could reflect differential investments in firm-specific training (Kuratani, 1973), they may also reflect the idiosyncratic nature of production in large firms (Oi, 1983), or problems of monitoring worker performance that are exacerbated in larger firms.

The last point highlights a potential difficulty in distinguishing between firm-specific training explanations on one hand, and a broad class of implicit labor contract theories on the other. Both predict steeply rising wage-tenure profiles, though the implicit contract

theories make no assumptions about training. Instead, steeply rising wage profiles are offered by employers to reduce incentives to shirk (Lazear, 1981) or to attract workers with low quit propensities (Salop and Salop, 1976). Another difficulty, raised by several recent papers (Abraham and Farber, 1987; Altonji and Shakotko, 1987), is in the interpretation of wage-tenure profiles. They argue (and demonstrate) that the estimated tenure coefficient in cross-sectional wage models is upward biased by omission of measures of job-match quality. Both issues are addressed for the U.S. case using information on reported training, and evidence is found to support the maintained hypothesis that wage-tenure profile differences are attributable primarily to specific-training investments.

Section I provides the justification for the technology-specific skills model, and reviews both U.S. and Japanese labor market research for insights into the link between technical change and human capital investments. Section II describes the U.S. and Japanese data, and the specification of the earnings models to be estimated. Section III presents the empirical results and discusses the similarities and differences in the relationship between technical change and skill acquisition in the two labor markets. Several qualifications about the interpretation of wage-tenure profiles are also addressed here. The conclusions are summarized in Section IV.

I. THE LINK BETWEEN TECHNICAL CHANGE AND HUMAN CAPITAL

The relationship between technical change and skill acquisition is based on an economic model of technology-specific skills (Tan, 1980). This model draws upon, and integrates, elements from the technical change literature, human capital theories (Becker, 1975), and the allocative efficiency of schooling hypothesis (Welch, 1970). The hypotheses are that individuals working with new technologies acquire new and more productive skills specific to that technology, and that better educated workers are more adept in this learning. The theoretical justification for these hypotheses are developed below.

The Technology-Specific Skills Model

Consider the notion that skill acquisition is greater in more technologically progressive firms. We know from microeconomic studies of the innovative process that much of the productivity gain from introducing a new technology comes from making cumulative small modifications in it, essentially through an intensive learning-by-doing process (Enos, 1962; Hollander, 1965). Indeed, the Horndal effect--a phenomenon in which labor productivity increases of 2 to 4 percent per annum are observed in plants with fixed facilities--may be a consequence of these learning and innovative activities. If so, then innovative firms have an incentive to motivate increased worker investments in learning about new technologies and to monopolize the new information embodied in workers' skills.

They can do this by sharing in the costs of skill acquisition and paying workers out of that component of productivity that is specific to the innovating firm. The familiar bi-lateral monopoly problem associated with skill specificity (Becker, 1975) arises here as well. On one hand, workers have few incentives to learn about new technologies since skills acquired may not be readily transfered to alternative uses; furthermore, such skills are subject (presumably) to more rapid rates of obsolescence when innovation is high. Employers, on the other hand, are

denied any innovative rents since new technologies cannot be used effectively without these skills. The solution is for worker-firm sharing of the costs and returns to specific training (Hashimoto, 1979). "Lifetime employment" guarantees could allay concerns about risky skill-investments, and encourage increased training and retraining as vintage skills become obsolescent over time.

technically skilled workers, especially at the outset of a new technology when experience is limited. This assertion is based on the argument that more educated workers are better adept at critically evaluating new information, and therefore learn more (Welch, 1970). The evidence from U.S. farming appears to support the hypothesis about schooling's "signal-extraction" effects. The schooling attainment of farmers is positively correlated with farm incomes and with the speed with which they allocate resources in a dynamically changing environment (Schultz, 1975). Several case studies also document the decline in the industrial demand for educated workers as technologies become routinized and widely diffused (Setzer, 1974). More broadly based empirical research by Bartel and Lichtenberg (1987) reveals that the relative demand for educated workers across manufacturing industries declines as the capital stock (and presumably the technology embodied in it) ages.

These perspectives provide the basis for the model's predictions about the relationships between technical change, specific training, and schooling. Unlike firm-specific human capital, which is thought to be idiosyncratic, technology-specific skills are hypothesized to be firm-specific only insofar as the company retains exclusive access to that technology. Over time, these embodied technology-specific skills become general as that technology diffuses to other firms; accordingly, the quasi-rents which these skills command also fall. However, firms which innovate faster than the rate at which their technologies diffuse to others can continue to generate new skills and quasi-rents. Thus, this model predicts systematically higher returns both to specific training and to schooling in firms experiencing rapid technical change.

Rapid economic growth may also lead to increased firm-specific training. For a given product, the derived demand for skills specific to that particular production technology is likely to vary

systematically with the rate of output growth. To the extent that demand growth outstrips the ability of the labor market to supply these skills (firms can either develop these skills internally or hire workers away from competitors using the same production technology), employers must devote increased resources to developing these technology-specific skills inhouse. Thus, holding technical change constant, this ancillary hypothesis predicts that firms in rapidly growing industries invest more in specific-training than slow-growing firms.

Another implication of the model--that long-term jobs are likely to be found in more technologically progressive industries--follows from skill-specificity. In essence, neither workers nor employers have any incentive to invest in specific training in the absence of a durable employment relationship. Though we do not explicitly examine this implication of the model, it is useful to briefly review several recent studies that seek to explain Japanese lifetime employment and wage practices in terms of technological change.[1]

A Selective Review of Japanese Research

A major focus of labor market research in Japan has been on explaining "dualism" in the wage and employment practices of large and small firms. Large firms in Japan not only pay higher wages but also extend the guarantee of lifetime employment to workers, in contrast to small firms where pay is lower and labor turnover higher. One explanation for this dualism is that it is technology-induced. Taira (1970) dates the origin of lifetime employment and *nenko-joretsu* (seniority-based) wage practices in Japan at sometime during the 1920s and 1930s. These practices were adopted primarily by large firms--who were the major importers of foreign technology--to reduce high rates of labor turnover (by present day standards) among skilled workers. Dualism exists, he argued, because of the coexistence of large firms using modern technology and small firms using traditional (indigenous) production methods.

[1]Tan (1982) provides a comprehensive survey of the recent literature on wage determination in Japan.

Yasuba (1976) extends this line of argument to examine the model's implication that firm-size wage differentials in an industry increase with the induction of foreign technology, but subsequently diminish with its diffusion to other firms in the industry, including small firms. For four cross-sections in time from 1909 to 1951, he allocates industries to either a "dualistic" or a "homogeneous" category on the basis of the coefficient of variation (to measure wage spread) and the size elasticity of wages (to measure the association of high wages and firm size). With information on which industries had purchased foreign technology and when, Yasuba finds considerable support for this hypothesis. For example, the period preceeding World War I was a period of rapid foreign-induced technical change in textiles, and six of ten dualistic industries were textile-related. In later years, the dualistic industries were no longer concentrated in textiles, and in fact, for the apparel and hosiery industries, firm-size wage differentials narrowed in the face of generally widening trends. Iron and steel, brick and tile, and printing industries all experienced rapid technical change after World War II and appeared in the dualistic category. These findings suggest that firm-size wage differentials in dualistic industries may be associated with quasi-rents from the use of foreign technology by large firms, rents which disappear when technology is widely diffused to other firms.

Research by Saxonhouse (1976) also establishes a link between the nature of technology and labor turnover. He speculates that the use of identical technology contributed to high labor turnover in the Japanese cotton-spinning industry at the turn of the century. He rejects the hypothesis that employers had few incentives to retain workers because no productivity advantages were gained by increased tenure in the firm. Estimating a translog production function whose parameters are explained by variables such as schooling, years of tenure, and the number of trained engineers, he finds that increases in these variables had large productivity effects. This finding leads him to conclude that the uniformity of technical practices among firms using identical English looms inhibited incentives to train workers since skills were easily

transferred to other competing firms. Some skills, it appears, are specific to particular production technologies and not necessarily to the firm. As such, incentives to invest in training workers are diminished unless institutional arrangements--such as lifetime guarantees or seniority-based wage and promotion practices--are developed to cement worker-firm relationships.

A study by Tan (1980) suggests that inter-industry differences in the rate of technical change are related systematically with some components of earnings but not others. Using data from the 1961 Basic Wage Survey of male workers in 11 manufacturing industries for which independent estimates of technical change were available, Tan estimated separate wage models for each schooling, occupation and education group by industry.[2] From the estimated wage profiles, present values of specific training (ST) and general training (GT) returns were calculated for each group of workers, assuming continuous employment in the same firm for 35 years. These wage components were regressed on estimates of industry rates of technical chage (TFP) and a set of controls for structural factors such as unionization (UNION), market concentration (CON), profitability (PR), and the share of wage bill in value-added (WB). These regression results are reported below:

$$ST = 8334 + 1496^{*}\,TFP + 677\,HS + 525\,JC + 4351^{*}\,UNIV - 11\,CON - 47\,PR - 36\,WB - 81\,UNION \qquad R\text{-square} = 0.525$$

$$GT = 3917 - 233\,TFP + 826\,HS + 7088^{*}\,JC + 7076^{*}\,UNIV + 23\,CON + 224\,PR + 77\,WB - 14\,UNION \qquad R\text{-square} = 0.771$$

where HS, JC and UNIV are dummy variables for high school, junior college and university completion, and an asterisk denotes statistical significance at the 1 percent level. From these results, Tan concluded

[2]The wage specification (and justification) used for the decomposition of earnings into general training and specific training components is similar to that discussed in Section II.

that higher rates of technical change in an industry are associated with an increase in specific-training, as measured by the present value of specific training returns (ST), but not with general training (GT). In other empirical specifications which considered the simultaneous determination of ST and TFP, this relationship remained very robust.[3]

To summarize, extant research appears to provide corroborative evidence for some of the predictions of the technology-specific skills model, at least for Japan. The issue is whether these perspectives carry over to the U.S. labor market, and to cross-national comparisons of U.S. and Japanese labor markets in a more recent period. We turn to these issues next.

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[3]Simultaneity might arise if the residual measure of TFP included specific training as one component of unmeasured labor quality so that TFP and ST are positively correlated. This possibility of simultaneity bias was addressed by formulating a structural model of ST and TFP, in which TFP is determined by ST and other inputs into the innovative process including the number of imported technology licenses, R&D spending, investments in new plant and equipment, and research staff. Allowing for the endogenous determination of ST and TFP reduced, but did not change, the positive effects of technical change on specific training investments.

II. DATA AND MODEL SPECIFICATION

The data used for the analysis come from two sources: the May 1979 Current Population Survey (CPS) for the United States, and the 1977 Employment Status Survey (ESS) for Japan. Both surveys are broad-based representative samples of the labor force in each country. The data are also from approximately the same time period and, in terms of the business cycle, in the recovery phase following the international recession of the mid-1970s. Most importantly, both surveys contain similar kinds of information on earnings, job tenure in the current firm, establishment size, schooling attainment, occupation and industry. Thus, the same model specifications can be used in studying the determinants of earnings in both countries.

In both data sets, analysis is limited to males between the ages of 18 and 65 years engaged fulltime in non-agricultural wage and salary employment. For the CPS, responses to questions on usual weekly earnings and hours worked are used to construct an hourly wage variable, W. For the ESS, the corresponding wage variable is created from annual earnings which include both contractual wages and semi-annual bonus payments,[1] and from usual weekly hours worked.[2] To mitigate labor supply effects on earnings, only those who worked full-time full-year are included in the Japanese sample. The vector of personal attributes included years of schooling attainment (S), prior work experience (EXP), and job tenure (TEN).[3] Indicator variables were also defined for white-

[1]Semi-annual bonuses are an important component (as much as one-third) of total wage compensation in Japan. Hashimoto (1979) argues that these bonus payments represent the worker's share of specific training returns.

[2]In the ESS, the weekly hours worked variable is reported in broad categories which may result in some (unknown) measurement error in the construction of hourly wage rates.

[3]Unlike the CPS where schooling attainment is continuous, this variable is categorical: middle school (8 years), high school (12 years) and college (16 years) graduates.

collar occupations (WCOLAR), geographic location, and residence in metropolitan areas. A common definition of firm size was used in both data sets: small firms with less than 100 employees, medium size firms with 100-999 employees, and large firms with over 1000 workers. The CPS also contained information on union membership not found in the Employment Status Survey.

Measures of industry rates of total factor productivity (TFP) growth estimated by Jorgenson, Gollop and Fraumeni (1986) for the United States and by Kuroda (1985) for Japan are merged into the two data sets by industry of current employment.[4] The U.S. TFP series is for the 1966 to 1979 period, and that for Japan for the 1966 to 1977 period. These measures have several advantages over alternative proxies for technical change. First, both measures of technical change derive from a common methodological approach which facilitates comparison of their effects on earnings across countries. Second, because these measures already adjust for changes in the quality of human capital inputs, the estimated correlations between technical change and the returns to technology-specific skills can be interpreted as reflecting the relationships of interest rather than a spurious correlation between wages and labor quality in the unadjusted technical change measure.

Two other industry attributes are merged into the data by industry of current employment: rate of output growth (IGR) and output variability (IVAR). Separate regressions of output on a quadratic specification of time were run for each two-digit industry, using annual output data for the U.S. (1960 to 1979) and Japan (1960 to 1977). The coefficient of the linear trend variable is used as a measure of output growth; the mean squared error of the regression is used as a proxy for the degree of cyclical variability around trend output growth. Though not central to the major thrust of this paper, IVAR is used to control for possible compensating wage effects for employment in industries with predictably high cyclical output variability.

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[4] I am grateful to Professor Kuroda for kindly providing estimates of industry rates of total factor productivity growth in Japan, as well as the input series used to create the TFP measures. Similar thanks go to Professors Gollop and Jorgenson for the companion TFP series for the U.S.

Table 1 summarizes some of the variables of interest for the U.S. (Panel A) and for Japan (Panel B), for the aggregate sample and separately by firm size. Several cross-national differences are noteworthy. First, the sample of U.S. workers has more schooling (about two extra years); they spend approximately the same amount of time working for other firms prior to joining the current employer, and on average they have shorter job tenure. The Japanese sample is older, possibly because those who were not working full-time full-year (predominantly youths) were dropped from the sample (see sample selection criteria). For this sample, however, the fraction of total work experience spent in the current firm (job tenure divided by total

Table 1

COMPARISONS OF WORKERS AND INDUSTRY ATTRIBUTES
IN THE U.S. AND JAPAN BY FIRM SIZE

Worker and Industry Characteristics	Aggregate Sample	Small Firms	Medium Firms	Large Firms
A. U.S. Sample				
Log(Hourly Wage)	1.906	1.816	1.974	2.119
Schooling	12.883	12.745	12.901	13.358
Previous Experience	8.778	9.490	8.394	6.848
Job Tenure	8.070	6.409	9.580	11.470
TFP 1966-1979	-0.198	-0.286	-0.130	0.005
IGR 1960-1979	2.195	2.473	1.893	1.715
IVAR	0.036	0.029	0.040	0.052
B. Japanese Sample				
Log (Hourly Wage)	-0.141	-0.312	-0.102	0.138
Schooling	11.014	10.423	11.518	11.681
Previous Experience	8.072	10.173	7.841	4.455
Job Tenure	12.150	11.165	11.241	14.654
TFP 1966-1977	1.571	1.132	1.822	2.164
IGR 1960-1977	4.004	4.511	3.786	3.260
IVAR	0.093	0.097	0.092	0.085

Note: TFP = Industry Total Factor Productivity Growth
IGR = Industry Output Growth
IVAR = Industry Output Variability

work experience) is slightly higher in Japan than in the United States. Secondly, for both countries workers in large firms are characterized by higher average schooling attainment, longer job tenure, and a smaller fraction of total work experience spent in previous jobs. Finally, note that the average industry rate of technical change imputed to individuals rises with firm size in both countries, suggesting that industries with high rates of technical change tend on average to have larger firms. In contrast, rapidly growing industries appear to have a disproportionately high number of smaller firms.

THE WAGE MODEL

The technology-specific skills hypothesis may be tested using an expanded specification of the conventional cross-sectional wage model. Consider the following wage model where, for expositional simplicity, quadratic experience terms are suppressed (these, and other interacted terms, are included in the empirical analysis):

$$\ln W_i = \alpha_1 + \alpha_2 S_i + \alpha_3 EXP_i + \alpha_4 TEN_i \qquad (1)$$

where for individual i, lnW = logarithm of hourly wages, S = years of schooling, TEN = years of tenure with the current employer, and EXP = years of previous labor market experience, defined as age minus S minus 6 less years of current job tenure.

This specification of the wage model has been used by a number of recent studies to decompose earnings into the returns to specific and general skill components (Chapman and Tan, 1980; Mincer and Jovanovic, 1981). The rationale is that when skills are completely general, no distinction need be made about where experience is acquired and general training returns are adequately captured by the coefficient of total labor market experience, EXP + TEN. On the other hand, if specific training increases a worker's productivity more in the current firm than elsewhere, the two experience measures should be entered separately. The added wage effects of TEN over and beyond those of EXP (i.e. α_4-α_3) may be interpreted as reflecting the returns to firm-specific training

on the current job.[5]

Equalization of the present values of training costs and returns requires an inverse relationship between initial wages and subsequent rates of wage growth with tenure. Since investments in specific training are hypothesized to increase with technical change (TFP), the model predicts that starting wages are negatively related to TFP while wage-tenure profiles are positively related to TFP. Furthermore, controlling for TFP growth, investments in specific training are predicted to increase with the rate of output growth (IGR) so a similar pattern of lower starting wages and higher rate of wage-tenure growth varying with IGR is predicted. Finally, the proposition that schooling returns increase with TFP is tested in a straightforward fashion through an interaction term between schooling and the rate of technical change, SxTFP.

The following wage specification, where general training returns are constrained to be equal across firms, permits tests of these predictions:

$$\ln W_{ij} = \beta_1 + \beta_2 S_i + \beta_3 S_i x TFP_j + \beta_4 EXP_i + \beta_5 TEN_i + \beta_6 TFP_j + \beta_7 TFP_j x TEN_i + \beta_8 IGR_j + \beta_9 IGR_j x TEN_i \quad (2)$$

where j subscripts industry and i the individual. The technology-specific skills hypothesis is supported if firms experiencing rapid technical change have low starting wages (negative β_6) and higher rates of wage growth with tenure (positive β_7) coefficients, and a corresponding pattern of wage effects for output growth (negative β_8 and positive β_9). Furthermore, a positive coefficient on the interaction between schooling and TFP (β_3) would provide support for the "allocative efficiency of schooling" hypothesis.

[5]A problem (which is discussed later) is that steeply rising wage-tenure profiles may also reflect wage schemes designed to reduce incentives to shirk (Lazear, 1981) or to attract workers with low quit propensities (Salop and Salop, 1976).

III. THE EMPIRICAL FINDINGS

Two specifications of a log-linear wage model are estimated, where the logarithm of hourly wages (U.S. dollars or 100 Yen for Japan) is related to a common set of regressors in each country. In specification (1), these include years of schooling, quadratic forms of prior work experience and years of tenure with the current firm, an interaction between prior experience and tenure, controls for firm size, union membership (U.S. only), occupation and location.[1] Specification (2) adds industry estimates of total factor productivity growth (TFP) and their interactions with schooling and job tenure, output growth (IGR) and IGR interacted with job tenure, and a control for the degree of industry output variability (IVAR).

Table 2 reports the results of estimating these OLS wage models for the two countries. The estimated coefficients of specification (1) are broadly similar in the two countries, and resemble those reported elsewhere in the literature (for example, see Hashimoto and Raisian, 1985). Generally, they suggest a pattern of wage growth increasing with schooling attainment, and with both prior work experience and years of tenure. In both countries, tenure on the current job is on average rewarded more highly than prior work experience, a result we interpret as tentative evidence for the presence of firm-specific training.

Nonetheless, hourly wages in the two countries differ in several important respects. First, Japanese firms appear to reward education more highly than U.S. firms (5 percent versus 4 percent). Second, both measures of work experience are associated with more rapid wage increases in Japan than in the United States--4.4 percent versus 3.0 percent for outside experience, 6.3 percent versus 4.3 percent for job tenure, respectively. These results imply not only greater skill

[1]This interaction term adds flexibility to the model specification since the returns to job tenure are allowed to vary with prior work experience. We would expect lower investments in specific training for those with long prior experience since remaining time on the current job is correspondingly shorter.

Table 2

RESULTS OF WAGE REGRESSIONS FOR THE UNITED STATES AND JAPAN

Dependent Variable: Log (Hourly Wage)

Variable Name	U.S. (1)	U.S. (2)	Japan (1)	Japan (2)
Constant	.817	.772	-1.572	-1.511
	(30.41)	(25.74)	(62.08)	(47.14)
Schooling (S)	.042	.046	.051	.051
	(22.73)	(24.75)	(36.77)	(29.29)
Prior experience	.031	.030	.044	.044
	(22.22)	(21.94)	(39.19)	(38.78)
Experience-squared	-.0006	-.0006	-.0008	-.0008
	(16.18)	(15.75)	(30.33)	(30.16)
Experience x tenure	-.0012	-.0011	-.0013	-.0013
	(17.06)	(16.49)	(26.49)	(26.03)
Tenure	.043	.038	.063	.057
	(26.28)	(14.91)	(51.64)	(20.33)
Tenure-squared	-.0008	-.0006	-.0009	-.0008
	(16.39)	(9.31)	(28.75)	(10.66)
Medium size firm	.085	.066	.158	.146
	(8.74)	(6.69)	(19.92)	(18.06)
Large size firm	.158	.115	.310	.290
	(12.88)	(8.98)	(39.76)	(35.36)
IVAR		1.699		.287
		(9.67)		(1.78)
TFP x schooling		.0065		.0003
		(4.96)		(0.41)
TFP		-.1344		-.0092
		(7.27)		(1.06)
TFP x tenure		.0046		.0016
		(4.14)		(2.49)
TFP x tenure squared		-.0001		-.00001
		(3.13)		(0.55)
IGR		-.0331		-.0144
		(6.27)		(3.63)
IGR x tenure		.0026		.0008
		(2.86)		(1.43)
IGR x tenure squared		-.00005		-.00002
		(2.02)		(1.09)
R-squared	0.3162	0.3415	0.4776	0.4808

Note: 1. Region, metropolitan residence, occupation, and union membership (United States only) controls included but not reported.
2. Absolute value of t-statistics in parentheses.

investments (both general and firm-specific) in Japan than in the United States, but also a greater firm-specific component in Japanese training. To see this latter point, note that the relative returns to tenure and prior work experience are 1.43 (.063/.044) in Japan and 1.38 (.043/.031) in the United States. Finally, hourly wages across firm size are much more highly differentiated in Japan than in the United States. Comparing the largest firm size (over 1000 employees) to small firms employing less than 100 workers (the omitted category), large employers in Japan pay wages that are over 30 percent higher; the corresponding figure in the United States is about 16 percent. (Results are reported separately by firm size in Table 4).

The second wage model addresses the issue of whether inter-industry wage-tenure profiles vary systematically with the industry rate of TFP growth and output growth, IGR. As hypothesized, higher industry rates of technical change are associated with lower starting pay (as measured by the coefficient of TFP) and higher rates of wage growth with job tenure (coefficient of tenure interacted with TFP). Controlling for TFP, industry wage-tenure profiles also appear to vary systematically with IGR, with lower starting pay and higher rates of wage growth with tenure in rapidly growing industries. The estimated parameters for the U.S. sample are statistically significant at conventional levels; while individual parameters for Japan attain statistical significance, the relationships of interest are not measured very precisely. The interaction between schooling and technical change is also positive and statistically significant for the U.S. sample, which is consistent with the "allocative efficiency" hypothesis. Interestingly, no support for this hypothesis is found for Japan--while positive, the coefficient of S interacted with TFP is not statistically different from zero. We speculate that this result may reflect the relatively unspecialized nature of public education in Japan or, alternatively, the greater emphasis placed on team production in which individual contributions (of more educated workers) are not easily identified.

Table 3 provides a convenient summary of the estimated results by comparing the predicted wage-tenure profiles under several different assumptions about TFP and IGR. A convenient starting point is at the mean level of TFP and IGR (case 1). Ignoring the quadratic term (which is very similar in both countries), the steeper wage-tenure profile in Japan implies that Japanese companies on average invest over 50 percent (5.22/3.29) more in their workers' specific training than their American counterparts. For the U.S., a standard deviation increase in TFP (case 2) is associated with a steepening of tenure-wage growth from 3.29 percent to 3.84 percent; a standard deviation increase in output growth (case 3) increases wage growth to 3.67 percent. The corresponding increases in Japanese firms are marginal at best, given the poor fit of the model. Part of the reason for this, as we shall see below, is attributable to aggregation across firm size in the Japanese sample.

Table 3

PREDICTED WAGE-TENURE PROFILES IN THE UNITED STATES AND JAPAN
FOR ALTERNATIVE TFP AND OUTPUT (IGR) GROWTH ASSUMPTIONS

COUNTRY	ASSUMPTIONS		
Wage-tenure growth profile	(1) Mean TFP and IGR	(2) 1 s.d TFP increase	(3) 1 s.d. IGR increase
1. United States			
Intercept [1]	1.9818	1.9237	1.9343
Linear wage growth	.0329	.0384	.0367
Quadratic term	-.00081	-.00087	-.00084
2. Japan			
Intercept	-.3349	-.3503	-.3632
Linear wage growth	.0522	.0549	.0537
Quadratic term	-.0009	-.0009	-.0009

Source: Table 2

Notes: 1. Excluding tenure and its interactions with TFP and IGR, the intercept is evaluated at the sample means of the explanatory variables, plus half the standard error of log(hourly wage).

Table 4 presents separate estimates of equation (2) for the three firm size groups in the two countries. Though qualitatively similar to the previous results, several systematic differences across firm sizes and between countries are noteworthy. First, consider the returns to schooling. Large firms in both countries reward schooling more highly than small firms--in going from the smallest to the largest firm size category, the returns to schooling increase from 4.3 to 5.0 percent in the United States and from 4.3 to 5.7 percent in Japan. Second, like the previous results, a systematic effect of TFP growth on schooling is found in the United States but never in Japan. Furthermore, in U.S. industries characterized by rapid TFP growth, highly educated workers in large firms are paid more than "similar" employees in small firms. To see this, compare the SxTFP coefficient in large firms (1.2 percent) and in small firms (.05). Thirdly, wage-tenure profiles in small U.S. firms appear to be steeper than that of large firms (4.5 percent versus 3.3 percent), a difference that is further amplified in industries with high TFP growth (the tenure-TFP interaction in small firms is .0075 and .0033 in large firms). In contrast, the tenure-TFP coefficients only attain statistical significance for the largest firm-size category in Japan. Finally, the effects of output growth, IGR, on wage-tenure profiles are most pronounced (and statistically significant) for medium-size and large firms in the United States and again only for the largest firms in Japan.

To summarize, on the most general level these results suggest that firms in technologically progressive industries invest more in their workers' specific skills, and that Japanese firms on average invest more heavily in training workers than their American counterparts. These results appear to stem from two sources--from increased skill investments in industries where learning possibilities are greater; and, for a given technology, from increased specific-training investments induced by rapid output growth.

The firm-size comparisons suggest some intriguing differences between the United States and Japan. Taken together, the estimated partial effects of TFP and IGR on wage-tenure growth suggest that

Table 4

WAGE REGRESSIONS FOR THE UNITED STATES AND JAPAN BY FIRM SIZE

Dependent Variable: Log (Hourly Wage)

Variable Name	U.S. SMALL	U.S. MEDIUM	U.S. LARGE	Japan SMALL	Japan MEDIUM	Japan LARGE
Constant	.739	.903	.984	-1.3492	-1.4289	-1.2566
Schooling (S)	.043	.047	.050	.043	.058	.057
	(16.63)	(14.28)	(1 .35)	(16.87)	(15.86)	(17.02)
Prior	.031	.028	.028	.039	.046	.046
experience	(7.12)	(10.76)	(7.43)	(23.96)	(20.24)	(20.97)
Experience	-.0006	-.0005	-.0005	-.0007	-.0008	-.0008
squared	(12.56)	(7.62)	(4.86)	(20.01)	(15.55)	(14.58)
Experience x	-.0012	-.0010	-.0010	-.0011	-.0015	-.0015
tenure	(11.85)	(8.91)	(5.84)	(14.45)	(13.52)	(16.30)
Tenure	.045	.034	.033	.052	.061	.051
	(10.31)	(8.74)	(6.89)	(11.41)	(11.41)	(11.28)
Tenure	-.0008	-.0005	-.0006	-.0008	-.0007	-.0006
squared	(6.78)	(5.00)	(4.67)	(6.73)	(5.12)	(5.27)
IVAR	2.324	1.273	1.602	-.338	-.312	.833
	(7.69)	(4.80)	(4.60)	(1.12)	(1.01)	(3.74)
TFP x S	.0055	.0071	.0118	.0015	-.0015	.0004
	(2.94)	(3.15)	(3.47)	(1.42)	(1.13)	(0.36)
TFP	-.1198	-.1468	-.2035	-.0111	0.0124	-.0133
	(4.57)	(4.59)	(3.93)	(0.81)	(0.65)	(0.81)
TFP x tenure	.0075	.0035	.0033	-.0003	.0025	.0028
	(4.29)	(1.82)	(1.31)	(0.32)	(1.67)	(2.33)
TFP x tenure	-.0002	-.0001	-.0001	.0000	-.0001	-.0000
squared	(3.67)	(1.10)	(0.90)	(1.16)	(1.72)	(1.23)
IGR	-.0231	-.0404	-.0373	-.0088	-.0150	-.0431
	(2.93)	(4.53)	(3.13)	(1.45)	(1.86)	(5.75)
IGR x tenure	.0003	.0040	.0038	.0007	.0004	.0037
	(0.19)	(2.62)	(2.16)	(0.82)	(0.38)	(3.69)
IGR x tenure	-.0000	-.0001	-.0000	-.0000	-.0000	-.0001
squared	(0.37)	(1.96)	(1.08)	(0.21)	(0.05)	(2.38)
R-squared	0.3004	0.3390	0.3239	0.3488	0.4862	0.5034

Note: 1. Region, metropolitan residence, occupation, and union (United States only) controls included but not reported above.
2. Absolute value of t-statistics in parentheses.

specific-training investments in small U.S. firms are more responsive to technological possibilities while training decisions in larger firms are driven more by output growth, given existing technology. In Japan, on the other hand, both factors are operative but only in the largest firm size category. In small Japanese firms, some part of training appears to be firm-specific, but it is neither related to TFP nor IGR. Their use of technologically standardized machinery, or reliance on large firms for technical expertise (many are subcontractors to large firms), may mean that small Japanese firms invest relatively little in new, more productive skills of the kind that are related to technical change.

WHAT DO THESE EARNINGS DIFFERENCES REFLECT?

The previous results, while suggestive, are nonetheless subject to two qualifications. First, do steeply rising wage-tenure profiles really reflect firm-specific training or are they the outcome of wage incentive schemes suggested by implicit contract theories which make no assumptions about training? Second, are wage-tenure effects a meaningful measure of specific training returns or simply a statistical artifact of an omitted firm-worker match variable in a cross-sectional wage equation? These two qualifications are addressed below.

Specific Training and Implicit Contract Interpretations. The problem of distinguishing between the firm-specific training and recent implicit contract theories has been noted by Parsons (1986) and others. These models share a common feature: they predict rapid growth of wages in the current firm relative to opportunity wages elsewhere. Denote this pattern of relative wage growth with tenure t by W(t). In one approach, workers forgo high initial wages to invest in firm-specific training which only increases their productivity, VMP(t), and future wages, W(t), in the current firm. Since both firms and workers share initial specific training costs, subsequent returns are also shared so that $W(t) < VMP(t)$. In the agency and self-selection models, employers initially pay workers less than their value marginal product but offer them wage-tenure profiles which are steeper than their productivity growth, i.e. $W(t) > VMP(t)$. Such back-loading of wages relative to spot

marginal product serves to reduce incentives to shirk (Lazear, 1981) or to attract workers with low quit propensities (Salop and Salop, 1976; Viscusi, 1980). If early job separation occurs, workers forfeit the difference between their initial value marginal product and wage; in effect, workers post a bond guaranteeing their non-shirking on the job or their employment stability. In these models, then, W(t) grows with years of tenure even if VMP(t) is constant over time. Individual data on W(t) and VMP(t) needed to distinguish between the competing theories are rarely available to the analyst.

An alternative way of empirically distinguishing between the competing models is with data on worker training. If a positive association between company training and TFP growth is found, we may assume the previous results infer a causal relationship between increased firm-specific training and steeper wage-tenure profiles in high TFP industries. For the United States, we can draw upon the findings of a recent study of the determinants of private sector training by Lillard and Tan (1986). Using self-reported measures of training in the National Longitudinal Surveys (NLS) of Young Men and Mature Men, they estimated separate probit models of the likelihood of training from company training programs, business and technical schools, and miscellaneous other sources. Each probit model included a common set of regressors on schooling, race, labor force experience, the industry rate of technical change, and labor market conditions.[2] The TFP variable was interacted with indicator variables representing five levels of schooling attainment to allow for different technical change effects on the likelihood of training for more and less educated workers.

Table 5 reports selected results for the effects of technical change on the likelihood of training from each source, holding other factors constant. For both the Young Men (Panel A) and Mature Men (Panel B) samples, company training was significantly more prevalent in industries characterized by higher rates of TFP growth, especially among the more highly educated. In contrast, the likelihood of training

[2]The TFP measures in that study referred to the period between 1966 and 1973, and were derived from Gollop and Jorgenson (1980).

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TFP	-.1198	-.1468	-.2035	-.0111	0.0124	-.0133
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IGR	-.0231	-.0404	-.0373	-.0088	-.0150	-.0431
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R-squared	0.3004	0.3390	0.3239	0.3488	0.4862	0.5034

Note: 1. Region, metropolitan residence, occupation, and union (United States only) controls included but not reported above.
2. Absolute value of t-statistics in parentheses.

Table 5

EFFECTS OF TECHNICAL CHANGE ON THE PROBABILITY OF TRAINING: NLS YOUNG MEN AND MATURE MEN

Industry TFP Growth and Schooling Interaction	Source of Training		
	Company training	Bus. & Tech schools	Other Sources
A. NLS Young Men			
<12 years	4.250	18.005 **	7.035
12 years	1.250	-4.796 *	-5.062 *
13-15 years	0.283	-3.219	-7.542 **
16 years	9.866 **	-6.554	-8.612 *
16+ years	16.877 **	0.302	-13.354 **
B. NLS Mature Men			
<12 years	0.767	6.104	-.554
12 years	-5.976	8.708	-3.273
13-15 years	-1.232	-6.039	-17.600 **
16 years	-4.346	-17.591	-15.266 **
16+ years	32.111 **	-16.564	-5.786

Source: Lillard and Tan (1986), Table 3.6
Note: a. TFP indices are from Gollop and Jorgenson (1980)
b. Asterisks denote statistical significance at the 5 percent (*) and 1 percent (**) levels.

outside the firm of current employment--from business and technical schools and miscellaneous other sources--was lower in high-TFP industries, with the more educated being significantly less likely to get such training. These results are consistent with the view that rapid technical change leads to increased reliance on inhouse training (possibly because technology-specific skills are not readily available elsewhere), and to greater demand for educated workers who may adapt more readily to new technologies. The results provide independent confirmation for the maintained hypothesis that steeply rising wage-tenure profiles reflect specific-training investments, and not just a pure incentive scheme.

Comparable data on training are not available in Japan, which makes it difficult to verify the assertion that steeper wage-tenure profiles in Japan reflect more intensive specific training in that country than in the United States. Anecdotal information, however, suggests that Japanese firms invest more heavily in the enterprise-specific skills of their workers. For example, in a comparison of male workers in auto assembly plants in Detroit and Yokohama, Cole (1979) finds that Japanese workers received a higher proportion of training courses that were company-oriented as compared to their U.S. counterparts. A recent study comparing U.S. firms and Japanese firms operating in the United States finds striking differences in their hiring and training practices (Mincer and Higuchi, 1987). Compared to U.S. firms, Japanese firms in this country spend more on screening new hires, provide company training to a higher fraction of their American workforce (24 percent versus 13 percent) and, consistent with the firm-specific training model, have wage-tenure profiles that are steeper than those found in the U.S. sample.

Specific Training and Job Match Quality. The second question is whether positive tenure-wage effects reflect specific-training returns or the quality of the job-match. This issue is at the heart of several recent papers by Altonji and Shakotko (1987) and Abraham and Farber (1987). They argue that the positive cross-sectional association between job tenure and earnings does not imply additional increases in earnings with seniority over and above the returns to general work experience, but may actually reflect the returns to a good job-match (which is not observed by the analyst). Indeed, the Abraham-Farber results show that inclusion of a measure of completed job duration (an instrument for job-match quality) substantially reduces the returns to job tenure. If the effects of unobserved job-match quality are important, few inferences can be drawn from our wage models of the United States and Japan because of potential omitted variable bias in the estimated tenure coefficients.

The effects of job-match quality, however, may operate through the joint decisions of workers to get (and employers to provide) job training. A standard prediction of human capital theory is that firm-specific training increases with expected time on the job N (or expected job duration) since there is a longer period over which to amortize firm-specific investments costs. A higher quality job-match (and longer N) should therefore also result in a greater likelihood of firm-specific training, other things equal. Since job-match quality and training decisions are linked inextricably, it follows that the Abraham-Farber findings cannot be interpreted as a rejection of the firm-specific training hypothesis; they may simply reflect the omission of job training measures.

A recent paper by Tan (1988) follows this line of reasoning using comprehensive training information contained in a matched January-March 1983 sample of 4660 males from the CPS. Two types of training variables were considered: (1) "inhouse training," which combined participation in company training programs and informal on-the-job training, and (2) "outside training" from all other external sources such as traditional schools, and business and technical institutions. Training and earnings equations were estimated using a two-stage procedure suggested by Barnow, Cain, and Goldberger (1981). In essence, the procedure involved estimating separate probit models for each source of training, and including their fitted values as instruments in the earnings model which was then estimated by two-stage least squares. The specification of the wage model is similar to that used earlier, except that two indices of total factor productivity (TFP) growth estimated by Gollop and Jorgenson (1985) are used, one for the 1947-1973 period, the other for 1973-1979. TFP growth was separated into two time periods to investigate whether long-run TFP or short-run TFP had a more important effect on current earnings growth.

Table 6 presents selected results from the two-stage wage model and, for comparison, OLS regression results from a wage model with training treated as exogenously determined. Note that the size of the tenure coefficient is reduced dramatically from .026 to .0023 in the two-

Table 6

SELECTED RESULTS OF OLS AND TWO-STAGE WAGE MODELS WITH TRAINING

Dependent variable: Log-Weekly Wage (mean=5.845)
Sample size: 4171 observations

Variable Names	OLS Model	2 Stage Model
Constant	4.6782 **	4.2205 **
Years of Schooling	.01619 **	.01261 *
Labor market experience	.07645 **	.05866 **
Experience-squared	-.00147 **	-.00089 **
Years of tenure	.02614 **	.00227
Tenure-squared	-.00043 **	-.00004
TC 1947-73	.00711	-.00857
TC 1947-73 x tenure	.00076	.00027
TC 1973-79	-.04420 **	-.03906 **
TC 1973-79 x tenure	.00120 **	.00193 **
Inhouse Training	.13942 **	2.02830 **
Outside Training	.21293 **	1.04400 **

Source: January-March 1983 matched Current Population Survey.
Notes: 1. Other control variables not reported here include race, location, and state unemployment rate.
2. The training probit models included marital status, categorical schooling indicators, and training needed to get the current job as identifying variables.
3. Asterisks denote statistical significance at the 5 per cent (*) and 1 per cent (**) levels.

stage model, and the variable loses statistical significance. This result suggests that if the quality of the job-match is responsible for the widely reported cross-sectional wage-tenure coefficient (as suggested by Abraham and Farber), it appears to operate entirely through worker and employer training decisions. If this is the case, then wage-tenure profiles estimated from conventional cross-section data without training information may still provide a useful first approximation of investments in firm-specific training.

Several other points are noteworthy. First, the effects of training on earnings are large, especially training from inhouse sources. In going from the single equation to the two-stage results, not only do the coefficients on training increase, but their relative rankings change as well so that inhouse training increases earnings more than training from outside sources, which is more plausible. Secondly, consistent with the results reported earlier, the effects of technical change (1973-1979) on wage-tenure profiles remain largely unchanged in the two-stage model, with lower starting wages and higher rates of wage-tenure growth in technologically progressive industries. In fact, the effects of TFP on wage-tenure growth becomes even larger, the tenure coefficient rising from .0012 in the single equation model to .0019 in the two-stage model. Finally, contemporaneous earnings growth is only affected by recent total factor productivity growth--the interactions between long-run TFP growth and tenure are never statistically significant. This result is intuitively plausible if older vintage job skills are rendered obsolete by rapid technical change.

IV. SUMMARY AND CONCLUSIONS

The starting point of this paper was the proposition that many employment and wage practices found in the United States and in Japan may actually reflect rational labor market responses to the exigencies of technological change. New technologies, before they can be used effectively, require extensive modification and learning; less than optimal amounts of learning may result because of the bilateral monopoly issue associated with these new and more productive specific skills. By clarifying the property rights of employers and workers to these efficiency gains, long-term employment relationships and seniority-based wage and promotion practices create a context which induces the appropriate investments in learning. By viewing the emergence of these institutions as demand-induced, it follows that where there was less need to develop technology-specific skills, these labor market practices did not arise or were not retained.

To test this proposition, we presented a model of technology-specific skills which yielded several (refutable) predictions about the relationships between industry rates of technical change and output growth on one hand, and wage-tenure growth and schooling on the other. These predictions were tested using comparable labor market data for the United States and Japan. The hypotheses were strongly supported in the U.S. sample, both in the aggregate and by firm size, and among Japanese workers employed in large firms. The first hypothesis, that rapid technical change induces increased investments in specific skills, found support in steeper rates of tenure-wage growth in more technologically progressive industries. Holding the level of productivity growth constant, rapid output growth was also associated with faster wage growth with tenure. A related hypothesis--that more educated workers have better "signal extraction" abilities--also found support in the positive interaction between schooling attainment and technical change, but only in the U.S. sample.

Several competing interpretations for the empirical findings were also evaluated using information (some anecdotal) on training. Evidence was presented for the United States which indicated that rapid technical change leads to increased reliance on inhouse training, possibly because technology-specific skills are not readily available elsewhere, and to a lower demand for training from outside sources. These findings were interpreted as providing independent confirmation for the hypothesis that steeply rising wage-tenure profiles reflect specific-training investments, and not the (pure) incentive schemes derived from implicit labor contract theories. The findings of several recent papers on job-match quality--which indicated a potential bias in estimated wage-tenure profiles--were also shown not to be inconsistent with a specific training interpretation. Results were presented which suggest that the wage effects of job-match quality may actually operate through the joint decisions of workers to get (and employers to provide) job training. By implication, wage-tenure profiles estimated from conventional cross-sectional wage models without training information may provide a useful first approximation of specific-training returns.

Overall, the cross-national comparison has provided some insights into how U.S. and Japanese labor markets operate to provide the human capital skills required for productivity growth. Surely part of the Japanese success of rapid economic growth is attributable to more intensive job training, of both general and specific types, as revealed in higher returns to both general work experience and job tenure in Japan than in the United States. Our empirical analyses were only successful in explaining part of the systematic inter-industry and cross-national variation in wage profiles, and there, more successfully for the United States than for Japan. In this regard, the preliminary results reported here raise more questions than they answer. For example, how do we explain differences between the United States and Japan in the responsiveness of small and large firms to productivity growth? Why is schooling more productive in technologically progressive industries in the United States but not in Japan? Further refinement and tests of the technology-specific skills model are needed to address these (and other) issues.

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